JPEG2000 : present and future of the new standard

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ABSTRACT

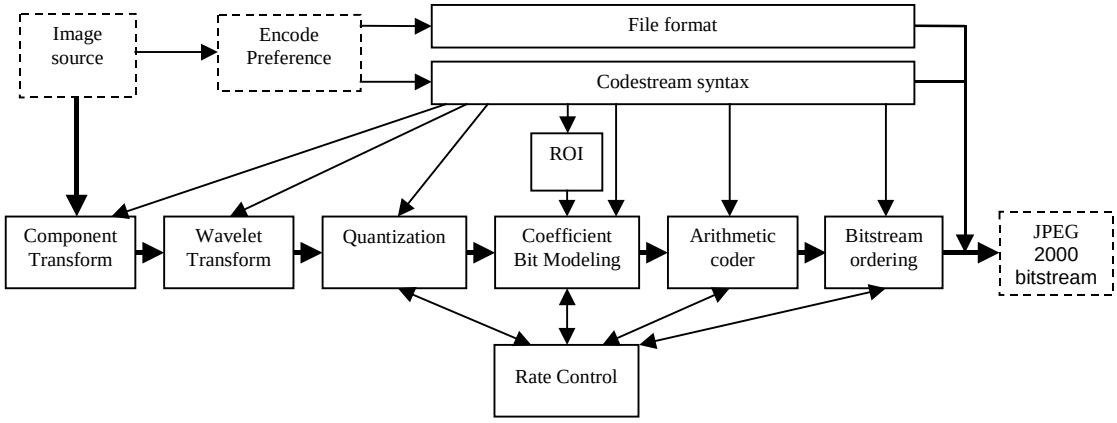
JPEG2000 is the most recent element in the large family of international standards developed by the Joint Photographic Expert Group (JPEG). The new JPEG2000 standard defines an image compression system that allows great flexibility not only for the compression of images but also for the access in the codestream. This paper presents briefly the different parts of the standard, already specified or currently in study. Other papers [8-15] in EUSIPCO 2002 provide further details on specific parts of the standard.

1. INTRODUCTION

The new ISO/IEC-ITU JPEG2000 image coding standard [1] provides better performances and extra features compared to the well-known JPEG coding standard.
A key feature of JPEG2000 is the flexible bit stream representation of the images suited for transmissions of a wide range of formats in heterogeneous environments, including error prone environments with optional error resilience tools (additional channel coding is not included in the standard). It allows also accessing to different representations of images using its scalability features (resolution, quality, position and image component) and the Region of Interest (ROI) feature taken into account at the encoder or decoder level. With this feature, an application can manipulate or transmit only the essential information for any target device from any JPEG-2000 compressed source image. The data flow can be then adapted to the user terminal capability, and offers a mechanism for interactive decoding.
There are already several parts in the standard, bringing necessary pieces of technology to build digital imagery applications. These parts are detailed hereafter. At the date of the publication of this document, six parts are already completed and four new work items are currently running (Part 8 to 11).

2. JPEG2000 part 1 Core Coding System

A complete description of JPEG2000 image compression standard can be found in the document ISO/IEC 15444-1 or ITU-T T.800 [1]. We propose hereafter only a short introduction to JPEG2000. A JPEG2000 encoder general scheme is given in the following figure.
An image can be described as a set of components: each sample of them being represented as unsigned or signed numbers of a certain bit depth. JPEG2000 is able to manage up to 2^{14} signed or unsigned components, with a precision from 1 to 38 bits per sample, and these components can have different size. Images having three RGB components can be decorrelated using a colour transform, which allows improving the compression efficiency. This is the only function of JPEG2000 Part 1 that relates components to each other.
Each image component may be divided into tiles, which are rectangular arrays of the same size, and coded independently. This feature allows reducing the amount of necessary memory to encode the image. The image partitioning into Tiles is described through a reference grid, an offset from this grid and a horizontal and vertical



space. Tile-components of an image can be extracted or decoded independently of each other. It is also possible to compress each particular tile with specific parameters. This tile independence provides one solution for extracting a specific area in the image.

The tile-components are decomposed into different resolution levels using a wavelet transformation using one of the two kernels available in Part 1: the irreversible 9/7 [4] or the reversible 5/3 [3] filter banks. The resolution levels contain a number of subbands coefficients [5] that describe the horizontal and vertical spatial frequency characteristics of the original tile-components.

For JPEG2000 lossless compression, it is mandatory to use the 5/3 filter bank. This filter bank through the rate allocation process allows also doing lossy compression, but for lossy compression, the use of the 9/7 filter bank is recommended.

The scalar quantization allows reducing the dynamic range of the wavelet coefficients before the entropy coding process.

When encoding a Region of Interest (ROI), an upshift of the coefficients bits related to this region is realized at the quantization level, to be downshifted at the decoding stage. The shape of the Region of Interest is not described in the JPEG2000 codestream; only the value of the shift is transmitted.

The individual quantized subbands of a tile-component are further divided into code-blocks. These rectangular arrays of coefficients are coded independently using an entropy coder at the bitplane level. This bit plane entropy coding is based upon the MQ algorithm combined with a bit context modelling [6]. Several options of the entropy encoder enable to provide error resilience mechanism, useful when transferring JPEG2000 image content in the context of error prone environments.

An efficient rate control mechanism proposed by the standard is based upon a rate distortion optimisation with Lagrange method. Through the rate control mechanism, the codestream data created from the entropy coding passes is organised in quality layers.

The JPEG2000 codestream syntax consists of marker segments that separate different data elements. The codestream contains a main header, followed by one or several tile parts. Code blocks of subbands at each resolution level are grouped into rectangular areas, called precincts that will be included in data packets. Packets are a fundamental unit of the compressed codestream. A packet contains compressed image data from one layer of a precinct for one resolution level of one tile-component. These packets are interleaved in the codestream using different ordering methods, that could be made through four axis: quality, resolution, component and position.

Packets related to a tile are grouped in one or several tile parts. A tile part header contains the information to decode the content of the tile part. The codestream can be included in an optional file format (JP2), which allows adding complementary information related to the image content, such as colour spaces, IPR information and other metadata.

3. JPEG2000 PART 2 EXTENSIONS

Part 2 of JPEG2000, approved in October 2001, offers extended encoding processes to satisfy specific applications, which were not considered essential to be integrated in Part 1 regardless to the most important requirements of the users. For example, in terms of wavelet transformations, with Part 2, the user can select any wavelet filters and can choose a particular wavelet decomposition, which is not limited to the dyadic one.

The quantization system supports the variable width of the deadzone in the scalar quantization and the Treillis Coded Quantization proposed by Marcellin in [7].

A block-based wavelet transform using a single sample overlap has been also introduced. This technique enables to considerably reduce the size of the memory at the wavelet transform level during the encoding and the decoding process.

The color transformation defined in Part 1 (RGB/YCbCr) has been extended for images that have more than three components. It can be used, for example, for the compression of CMYK images, multiple component medical images, and any other multiple component data. An extension for non-linear transformations is also defined in Part 2.

The Region Of Interest, which is based on the Max Shift method in Part 1, has been extended to the scaling based method. In that case, the quantized transformation coefficients are scaled in such a manner that the relative significance of each transformation coefficient is equal to a specified scaling value of the ROI to which it applies.

In the Part 1 JPEG2000 standard, the JP2 file format provides a method by which applications can interchange images files in such a way that all conforming readers can properly interpret and display the image. However, some applications require extensions to the JP2 file format that would prevent the file from being properly interpreted by a conforming reader. For example, a conforming JP2 reader will not properly interpret an image encoded in a CMYK colourspace. The goal of the proposed JPX file format is to considerably enrich the JP2 file format in order to offer more possibilities to the user in terms of color spaces, metadata (DIG35 metadata), composition and animation.

4. JPEG2000 PART 3 MOTION JPEG2000

This third part of the JPEG2000 family is devoted to video sequences and uses the wavelet-based JPEG2000 codec of

Part 1 for the coding and display of timed sequences of images. Consequently, Motion JPEG2000 sequences offer the same kind of functionalities as Part 1, like for example the lossless compression.
A specific file format, named MJ2, has been defined, and guidelines for the use of the JPEG2000 codec for timed sequences are supplied. The MJ2 file format, based on the MPEG-4 MP4 file format, is designed to contain one or more motion sequences of JPEG2000 images, with their timing, and also optional audio annotations, all composed into an overall presentation. Motion JPEG2000 provides a flexible format, permitting a wide variety of usages, such as editing, display, interchange, and streaming.
Motion JPEG2000 is expected to be used in a large range of applications, particularly where the codec is already available for other reasons, or where the high-quality frame-based approach, with no inter-frame coding, is appropriate. The targeted applications are digital still cameras, PC-based video capturing, high quality digital video recording, high-resolution medical and satellite imaging.

5. JPEG2000 PART 4 AND PART 5

5.1. Conformance testing

Part 4 defines a set of compliance tests to ensure correct implementation of JPEG2000 part 1.
Decoders, depending on their applications and capabilities may not support all the features supported by JPEG2000. Profiles and compliance classes have been created in order to define implementation restrictions. Effort has been made to limit the number of possible combinations and to ensure a minimum compatibility between decoders.
Profiles correspond to an encoder limitation in terms of JPEG2000 coding options and parameter ranges. These profiles define decoder capabilities needed to decode the produced codestream. Compliance classes ensure a minimum level of image quality for a decoder
A profile defines a codestream limitation whereas compliance class defines the decoding performances of a decoder. There are two profiles and three compliances classes defined for JPEG2000 Part 1. One important thing to mention is that Part 4 is only considering conformance points for the technologies included in JPEG2000 part 1. Together with compliance and test procedure definition, Part 4 provides conformance bitstreams, for the two profiles.

5.2. Reference software

In order to check the syntax defined in Part 1 and make easier the use of JPEG2000, two high quality free software implementations have been developed. Each of them provides a coder and a decoder compliant with JPEG2000 Part-1 standard. A Java version has been developed by the JJ2000 Partners (Canon France, Ericsson, Swiss Polytechnical School of Lausanne –EPFL–) and a C implementation by the University of British Columbia (Canada). Lots of bitstream exchanges have been performed between these two codecs to ensure the completeness and clarity of the Part 1 standard's text specifications. Both codecs are now freely available through JPEG web site (www.jpeg.org) and can be tested by anyone.

6. JPEG2000 PART 6: COMPOUND IMAGE FILE FORMAT

This specification, which will be finalized in late 2002, defines a normative but optional file format (JPM) for storing compound images using the JPEG2000 file format family architecture. This format is an extension of the JP2 file format defined in Part 1 and also uses some elements from the extended file format JPX.
This standard defines a binary container for multiple bi-level and continuous-tone images used to represent a compound image. A mechanism, based on the Mixed Raster Content model, has been defined in this recommendation to combine multiples images into a single compound image. Furthermore, another mechanism enabling to group multiple images into a hierarchy of layout objects, pages and page collections is also proposed. It is also important to note that this file format supports other compression system than JPEG2000 for images.

7. JPEG2000 PART 8: JPSEC

Security issues, such as authentication, data integrity, protection of copyright and intellectual property, privacy, conditional access are among important features in many imaging applications targeted by JPEG2000. A new part, referred to as JPSEC, has been created in late 2001 to focuse on this issue. JPSEC standard intends to provide tools and solutions allowing applications to generate, consume and exchange secure JPEG2000 bitstreams.

8. JPEG2000 PART 9: JPIP

While JPEG2000 has many benefits for non-interactive applications, such as image data transmission, the features of JPEG2000 (e.g. multi-resolution, scalability) are beneficial for interactive applications. In a typical use case scenario, a server could deliver a portion of the JPEG2000 file to satisfy some request from a client. This request could be formulated in terms of area of interest in the

image, the resolution level and the desired quality. In order to satisfy this scenario, it is important that the client and server have an intelligent “conversation” in order to fully interact.
This future standard, which was set up in November 2001, intends to specify an efficient protocol where structured series of interactions between a client and a server by which partial or whole image JPEG2000 codestreams, image file metadata and structures may be exchanged in an efficient manner. These structures would include definitions of the semantics and values to be exchanged, and would suggest how these may be passed using a variety of existing network transports.

9. JPEG2000 PART 10: JP3D

JP3D will provide extensions of JPEG2000 for logically rectangular 3-dimensional data sets with no time component and floating-point data sets. JP3D is envisioned as a pure extension of Parts 1 and 2, meaning that any compliant Part 1 or Part 2 codestream will be recognized as a compliant JP3D codestream. JP3D serves scientific computing applications and a handful of other specialized niche applications like volumetric imagery (medical computed images, industrial tomography or computed image, biological imagery) and remote sensing imagery (multi- and hyperspectral imagery, geophysical / astrophysical measurements).

10. JPEG2000 PART 11: JPWL

Part 11 is considering the wireless application needs for JPEG2000. In Part 1, useful mechanisms are provided to detect errors, at the syntax and coding levels. Nevertheless, it doesn't introduce any correction mechanism, enabling to take advantage of the codestream ordering, like Unequal Error Protection [15]. Part 11 will standardize the mechanisms enabling advanced error correction and/or handling.

11. CONCLUSION

JPEG2000 standards family offers outstanding compression performances (either higher image quality or lower bit rates) and a lot of new features required by a large field of applications.
JPEG2000 should be adopted very soon in many software and hardware applications as the successor of JPEG.

12. REFERENCES

[1] ISO/IEC 15444-1/ IUT-T T.800, “JPEG2000 Image Coding System - Part 1 : Core Coding System”, 2000.
[2] D. Santa-Cruz, T. Ebrahimi, “An analytical study of JPEG2000 functionalities”, ICIP2000, Vancouver, Sept. 2000.
[3] M. Rabbani, R. Joshi, “An overview of the JPEG2000 still image compression standard”, Signal Processing Image Communication, Eurasip, Volume17, No. 1, pp. 3-48, January 2002.
[4] D. Le Gall, A. Tabatabai, “Subband coding of digital images using symmetric kernel filters and arithmetic coding techniques”, Speech Signal Processing, Proceedings of the international conference on acoustics, New York USA, pp761-764, April 1988.
[5] M. Antonini, M. Barlaud, P. Mathieu, I. Daubechies, “Image coding using wavelet transform”, IEEE Trans. Image Process. 1 (2), pp205-220, April 1992.
[6] D. Taubman, E. Ordentlich, M. Weinberger, G. Seroussi, “Embedded block coding in JPEG 2000”, Signal Processing Image Communication, Eurasip, Volume17 No. 1, pp. 49-72, January 2002.
[7] M.W. Marcellin, T. R. Fischer, “Trellis Coded Quantization of Memoryless and Gauss-Markov Sources,” IEEE Trans Comm, January 1990.
[8] P. McCanny, S. Masud, J. McCanny, "VLSI Design and Implementation of JPEG-2000 compatible 2-D Inverse Discrete Wavelet Transform", EUSIPCO, Toulouse, France, September 2002
[9] I. Aouadi, O. Hammami, E. Zheng, "Exploration of Hardware Implementations of JPEG2000 Entropy Coder", EUSIPCO, Toulouse, France, September 2002
[10] C. Le Barz, R. Elmostadi, D. Nicholson, " Real time implementation of JPEG2000 ", EUSIPCO, Toulouse, France, September 2002
[11] C. Parisot, M. Antonini, M. Barlaud, "Model-based bit allocation for JPEG2000", EUSIPCO, Toulouse, France, September 2002
[12] M. Larabi, C. Fernandez-Maloigne, N. Richard, "Psychovisual evaluation of the effect of color spaces and color quantification in JPEG2000 image compression", EUSIPCO, Toulouse, France, September 2002
[13] A. Nguyen, V. Chandran, S. Sridharan, R. Prandolini, "Progressive coding in JPEG2000 - Improving content recognition performance using ROIs and importance maps", EUSIPCO, Toulouse, France, September 2002
[14] M. Iregui, B. Macq, "Optimal caching mechanism for JPEG2000 communication", EUSIPCO, Toulouse, France, September 2002
[15] C. Poulliat, P. Vila, D. Pirez, I. Fijalkow, "Progressive quality JPEG2000 image transmission over noisy channel", EUSIPCO, Toulouse, France, September 2002